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NAVAL AIR WARFARE CENTER WEAPONS DIVISION

DEPARTMENT OF THE NAVY

DEFINITIONS SPECIFICATION

FOR THE

JOINT ADVANCED MISSILE INSTRUMENTATION (JAMI)

TIME SPACE POSITION INFORMATION (TSPI)

UNIT MESSAGE STRUCTURE (TUMS)

DIGITAL PROTOCOL

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This specification consists of pages i to iv and pages 1 through 19, inclusive.

Approved:

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By Direction

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1.0 Scope.

1.1 Overview

This document consists of the Time, Space, and Position Information (TSPI) Unit Message Structure (TUMS) protocol that defines the word structure that is output by the JAMI TSPI Unit (JTU) in an air vehicle for the Telemetry (TM) link to the JAMI Data Processor (JDP) ground unit. The data is collected, processed and formatted in the JTU using the measurements from the Global Positioning System (GPS) Sensor Unit (GSU) and the Inertial Measurement Unit (IMU) which are components of the JTU. The digital data in the TUMS format is then sent to the air vehicle TM transmitter for transmission to the ground. The TUMS data structure follows the IRIG 106-01 Part II format.

1.2 Data source

The GSU and the IMU within the JTU each provide data that is sampled by the JTU Data Formatter Board (DFB). The sampling rates of the JTUDFB are controlled by synchronized pulse strobes from the GSU. The GSU samples GPS satellite data and outputs this GPS data to the JTU in synchronization with the epoch pulse strobe (EPS). The output of the six degree of freedom IMU will be six discrete analog voltages that are proportional to the vehicle accelerations and angular rates in three axis. These six analog outputs of the IMU sensors are sampled simultaneously by the JTUDFB in synchronization with the GSU strobe pulse. This analog IMU data is then converted to digital format, integrated, processed and formatted for the TUMS message. The processed IMU data is appended to the GSU data and a "Source Packet" header is added to create the TUMS data stream. Use of the IRIG 106-01 Part II standard makes this message structure compatible with standard National Range packet telemetry.

1.3 Data Synchronization

The timing relationship between the GSU data output and IMU measurements is critical and is maintained within 100 us. The IMU sample rate is a multiple of the GSU data update rate and the specific relationship shall be specified in system documents. The sampling rates are controlled by synchronized timing strobes from the GSU as described in the GSU and JTU specifications.

2.0 Applicable Documents.

2.1 Government documents, drawings, and publications

The following Government documents, drawings, and publications form a part of this document to the extent specified herein. Documents not identified by specific revision or date shall be the issue in effect at the time of the solicitation.

Documents

Naval Air Warfare Center Weapons Division

(Cage Code 12934)

NAWC-CH 3125	GPS Sensor Unit (GSU) Performance Specification, High Dynamic
NAWC-CH 3122	GPS Sensor Unit (GSU) Performance Specification, Low Dynamic
NAWC-CH 3119	JTU Assembly Performance Specification, High Dynamic

(Request for copies should be directed to Commanding Officer, Naval Air Warfare Center Weapons Division, Code 543E00D, China Lake, CA 93555-6100.)

STANDARDS

RANGE COMMANDERS COUNCIL

IRIG 106-01 Part II	Telemetry Networks

(Request for copies should be directed to Secretariat Range Commanders Council, U.S. Army White Sands Missile Range, New Mexico 88002-5110, or online at http://jcs.mil/RCC.)

3.0 Requirements

3.1 Message Structure

The overall TUMS message structure follows the packet structure of IRIG 106-01 Part II. Figure 1 below shows this structure adapted for the TUMS data. Each field is described below.

Packet Primary Header							Packet Data Field	
Version No	Packet Identification			Packet Sequence Control		Packet Data Length	Data Secondary Header	Source Data
	Type Indi-cator	Second-ary Header Flag	Application Process Identifier	Grouping Flags	Source Sequence Count			
000	*0*	*0*	*11001001101*	*11*	See text	*See text*	*Not Used*	*JTU Data*
3 Bits	*1 Bit*	*1 Bit*	*11 Bits*	*2 Bits*	*14 Bits*		*variable*	*variable*
2 Bytes				*2 Bytes*		*2 Bytes*	*1 to 65536 Bytes*	

Figure 1 TUMS Packet

3.2 Packet primary header

3.2.1 Version number

The version number shall be set to a binary 000.

3.2.2 Packet identification

The packet identification verifies the type of packet, indicates whether the packet carries a secondary header, and provides information on the source.

3.2.2.1 Type indicator

This is a single bit which shall be set to "0." This establishes that it is a Telemetry Source Packet.

3.2.2.2 Packet secondary header flag

This is a single bit which shall be set to "0." This indicates that there is not a secondary header.

3.2.2.3 Application process identifier

This field is 11 bits long and shall be the Identification (ID) Number for TUMS. The TUMS ID number, in binary, is 11001001101. This must be approved by the RCC.

3.2.3 Packet sequence control

The Packet Sequence Control Field provides a sequential count of the packets generated with the same ID number, and if the grouping feature is applied, provides information on the position of the Source Packet in a group.

3.2.3.1 Grouping flags

This is a two bit flag and shall be set to "11." This indicates that the TUMS packet is not part of a Group of Source Packets.

3.2.3.2 Source sequence count

This is a 14-bit field that shall provide the sequential binary count of each TUMS packet sent after power up or a power reset.

3.2.4 Packet data length

This field is two bytes long and shall contain the total number of bytes contained in the Packet Data Field minus 1.

3.3 Packet data field

This field shall follow the Packet Primary Header without a gap. It contains all the GPS and processed IMU data and ends with a checksum.

3.3.1 Packet data secondary header

Not used.

3.3.2 Source data field

The Source Data field starts with a status word and contains one epoch of data from the GSU and the associated processed IMU data for the present GSU epoch. An epoch is defined as a GPS cyclic measurement with a period between 0.1 and 0.05 seconds (10 to 20 Hz). During the epoch period the IMU sensors are sampled and processed. The period is determined by the configuration of the GSU installed. Table I shows the overall structure of the Source Data Packet. The number in parenthesis indicates the number of bytes needed for that data set.

TABLE I. Source Data Packet Structure

Source Data Field			
Status Word(2)	GSU Data(Variable)	IMU Data(Variable)	CKSUM(1)

3.3.2.1 Status word

The status word contains the TUMS message type identifier, five system health status bits that contain the results of the built in tests of certain sensors, and the JTU unit serial number. The word definition is shown in Table II with the functional description of the Bits in the following paragraphs.

TABLE II. Status Word

Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8,7,6,5,4,3,2,1**	**0**
Function	Type	Reset	GSU	Fail	Dynamic	Static	<<<<Unit serial number>>>>>		
							MSB		LSB

3.3.2.1.1 Unit ID Bit (9 - 0)

This series contains the JTU unit serial number with bit 9 as the most significant bit (MSB) and bit 0 as the least significant bit (LSB).

3.3.2.1.2 Static Bit (10)

This bit is set to "1" when all the IMU sensor outputs are equivalent to a static vehicle. Otherwise it shall be set to "0."

3.3.2.1.3 Dynamic Bit (11)

This bit is set to "1" when dynamic activity is detected on any IMU sensor. Otherwise it shall be set to "0."

3.3.2.1.4 Fail Bit (12)

This bit is set to "1" if any of the sensor outputs are near the rails or if the DC bias of the sensors is not in the expected range. Otherwise it shall be set to "0."

3.3.2.1.5 GSU Bit (13)

This bit provides information on the performance of the GSU. Upon power up the bit will toggle with a period of 2 seconds. This will indicate that GSU is powered and searching for satellite vehicles. When satellites have been acquired the bit will then toggle on for 1 second then off for 0.5 seconds followed by the bit toggling of 1-second period for each satellite tracked. Once all satellites have been counted, the bit will toggle off for 1 second and the reporting cycle will start over.

3.3.2.1.6 Reset Bit (14)

This bit shall be set for a period of one second after a processor reset has occurred.

3.3.2.1.7 Type Bit (15)

This bit shall be set to 1 for a TUMS Type I message and to 0 for a TUMS Type II message.

3.3.2.2 GSU (GPS) data structure

There shall be two TUMS structures identified as TUMS Type I and Type II. The header and IMU portions of these types are the same except that the GSU data portion is different depending on whether the GSU contains a complete GPS receiver and outputs raw and/or processed GPS data (Type I); or outputs sampled GPS satellite signals (Type II). The Type I format must meet the requirements of this paragraph in order to interface with the JDP software. The Type II format may be a vendor defined structure that has a header and ends with a checksum. The message structure shall be the same for either a Type I or II message except for the total number of bytes.

3.3.2.3 TUMS Type I GSU message structure

The TUMS Type I GSU message structure will consist of the Missile Application Condensed Measurement (MACM), Missile Application Time Message (MATM) and Position, Velocity, Time Message (PVTM) messages within the overall TUMS statement.

3.3.2.3.1 MACM message

The MACM message is a data format designed for high-speed output of raw GPS measurement data. The carrier-to-noise ratio, carrier phase measurement, pseudorange, carrier phase rate, elapsed lock time, and condition flags are supplied for each satellite being tracked.

3.3.2.3.1.1 MACM message format

The message consists of a header, an observation data line for each satellite under track, and the checksum for the MACM message. The message length depends on the number of satellites being reported, which is a maximum of 303 bytes for twelve satellites. Table III presents the format of a MACM message with seven satellites reported. This sample message is 183 bytes long. The definitions of the individual data fields within the MACM message are given in Table IV. Table V shows a pair of actual MACM messages. The contents and formats of individual data fields are amplified in Tables VI and VII. The MACM message can be interpreted when viewed on a hexadecimal viewer/editor.

TABLE III. MACM Record Format

Data	Function	Total Bytes
[MACM: 4] [VERSION: 1] [NUMOBS: 1] [GPSTIME: 4] [OFFSET: 4]:	Header	14
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[PRN: 1][CONDITION: 2][CN0: 1][PHASE: 8][PSRNGE: 4][RATE: 4][LOCKTIME: 4]	Observation	24
[CKSUM:1]	Checksum	1
Note: The number after a colon is the number of bytes associated with each field.		

TABLE IV. MACM Data Field Definitions

Byte #	Name	Type	Content
1 - 4	MACM	Char [4]	Sync_word (Name of message, ASCII "MACM")
5	VERSION	Unsigned char	MACM version number (set to 2)
6	NUMOBS	Unsigned char	Number of observations to be sent for the current epoch. (Each observation is one satellite.)
7	GPSTIME	Long	Time of validity, in ms of week GPS system time. This is the time tag for all measurements and position data.
11	OFFSET	Float	Receiver clock offset in meters
(24*j)-9	PRN	Unsigned char	Satellite PRN number
(24*j)-8	CONDITION	Unsigned short	Manufacturer defined warning and condition flags
(24*j)-6	CN0	Unsigned char	Signal-to-noise ratio of satellite observation (dB-Hz)
(24*j)-5	PHASE	Double	Carrier phase measurement in cycles. Measurements increase as the range increases
(24*j)+3	PSRNGE	Unsigned long	Pseudorange in seconds, scale factor = 3.0×10^{10}
(24*j)+7	RATE	Signed long	Rate of change of carrier phase, positive for increasing range. Scale factor = 1×10^{-4} Hz
(24*j)+11	LOCKTIME	Unsigned long	Continuous counts since satellite is locked. This number is to be incremented 500 times per second
(24*j)+15	CKSUM	Unsigned char	Checksum includes bytes 5 through the end of the message. (Checksum does not include bytes 1-4 nor the checksum itself.)

Notes:
a. j = 1,2, ..., N; where N = # of observations in the message (# of satellites, value of byte #6). The message is variable in length. The number of 24-byte observations is defined by the value of byte #6 in the header.
b. The message begins with the 4-byte sync_word [4D 41 43 4D] (ASCII "MACM") and ends with the checksum byte.
c. There are no carriage returns or line feed pairs associated with the message. Counting from the sync word does all parsing.
d. Time accuracy of observations: Times of validity for MACM records are required to be accurate to within 100 μs of true GPS time.
e. CKSUM is computed by the bit by bit exclusive ORing of all bytes in the block of data as defined in the table.

TABLE V. Example of MACM Hexadecimal Messages

Byte	Byte Number																								
Offset	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f	10	11	12	13	14	15	16	17	ANSI Character
000000	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
000018	00	4d	41	43	4d	02	06	0e	a0	0c	90	40	7c	10	00	02	02	05	24	c1	1c	27	ad	b6	.MACM... ..@|.....$Á.'-¶
000030	83	39	e0	7a	b4	24	64	00	96	be	29	00	09	6d	48	18	0a	05	29	c1	39	82	89	7c	.9àz´$d..¾)..mH...)Á9..|
000048	1b	61	a4	89	33	d2	34	fe	43	11	7e	00	00	95	6a	07	02	05	2b	c1	33	4f	3c	9e	.a¤.3Ò4þA.~...j...+Á3O<.
000060	05	a3	14	7e	58	d9	a6	00	0d	96	3b	00	0a	49	cb	09	aa	00	28	c1	3d	92	f9	54	.£.~XÙ¦...;..IË.ª.(Á='ùT
000078	e0	d4	a0	8c	d4	36	fa	ff	63	5c	85	00	00	04	65	0e	02	05	25	c1	2d	bf	f5	b9	àÔ .Ô6úÿc\....e...%Á-¿õ¹
000090	4d	05	18	8b	f8	67	a3	00	80	9c	42	00	09	cb	08	10	00	05	26	c1	37	44	bb	7d	M...øg£....Ë....&Á7D»}
0000a8	0b	c6	e0	84	a7	1c	e7	ff	41	00	68	00	00	60	c7	25	00	00	00	00	00	00	00	00	.Æà.§.çÿA.h..`Ç'........
0000c0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
0000d8	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
0000f0	00	00	00	00	00	00	00	00	00	00	00	00	00	4d	41	43	4d	02	06	0e	a0	33	a0	3f	.............MACM... 3 ?
000108	b8	c0	00	02	02	05	22	c1	1b	8d	09	d0	27	ee	00	7a	b7	03	4b	00	97	7d	25	00	¸À...."Á...Ð'î.z·.K..}%.
000120	09	80	d0	18	0a	05	28	c1	39	f4	6a	4c	f5	33	d0	89	2b	59	77	fe	43	7e	7a	00	..Ð...(Á9ôjLõ3Ð.+YwþC~z.
000138	00	a8	f2	07	02	05	2e	c1	33	4b	c5	3d	b7	31	a0	7e	59	1b	77	00	0d	bf	cf	00	.¨ò....Á3KÅ=·1 ~Y.w..¿Ï.
000150	0a	5d	53	09	aa	05	29	c1	33	ab	98	8d	f9	f9	80	8c	d1	3b	75	ff	64	11	ad	00	.]S.ª.)Á3«..ùù..Ñ;uÿd.-.
000168	00	12	d9	0e	02	05	25	c1	2d	7d	f9	a9	25	17	a0	8b	fa	db	bc	00	81	70	cf	00	..Ù...%Á-}ù©%. .úÛ¼..pÏ.
000180	09	de	90	10	00	05	26	c1	37	75	8e	e2	62	4e	40	84	a3	7a	fc	ff	41	d6	cc	00	.Þ....&Á7u.âbN@.£züÿAÖÌ.
000198	00	74	4f	38	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.tO:....................
0001b0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....

This sample contains two MACM messages. The first begins at offset byte 000019h and ends at byte 0000b8h. The next message starts at byte 0000fdh, and ends at 00019ch. Note that the messages may be preceded and followed by other bytes that are not part of the MACM message itself. These bytes are shown as zeroes, but may actually be any valid binary data stream, of any length.

TABLE VI. Interpretation of the first sample MACM message of Table V

MACM	VERSION	NUMOBS	GPSTIME	OFFSET			Field Name
4d 41 43 4d	02	06	0e a0 0c 90	40 7c 10 00			Hex
ASCII Text	2	6	245370000	3.938477			Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
02	02 05	24	c1 1c 27 ad b6 83 39 e0	7a b4 24 64	00 96 be 29	00 09 6d 48	Hex
2	Flags	36 (dB)	-461291.428234962747	2058626148	9879081	617800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
18	0a 05	29	c1 39 82 89 7c 1b 61 a4	89 33 d2 34	fe 43 11 7e	00 00 95 6a	Hex
24	Flags	41	-1671817.48479280714	2301874740	-29159042	38250	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
07	02 05	2b	c1 33 4f 3c 9e 05 a3 14	7e 58 d9 a6	00 0d 96 3b	00 0a 49 cb	Hex
7	Flags	43	-1265468.61727351416	2119752102	890427	674251	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
09	aa 00	28	c1 3d 92 f9 54 e0 d4 a0	8c d4 36 fa	ff 63 5c 85	00 00 04 65	Hex
9	Flags	40	-1938169.33155564219	2362717946	-10265467	1125	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
0e	02 05	2b	c1 2d bf f5 b9 4d 05 18	8b f8 67 a3	00 80 9c 42	00 09 cb 08	Hex
14	Flags	43	-974842.86191574018	2348312483	8428610	641800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
10	00 05	26	c1 37 44 bb 7d 0b c6 e0	84 a7 1c e7	ff 41 00 68	00 00 60 c7	Hex
16	Flags	38	-1524923.48846095055	2225544423	-12517272	24775	Interpretation
CKSUM							**Field Name**
25							Hex
00100101							Interpretation

TABLE VII. Interpretation of the second sample MACM message of Table V

MACM	**VERSION**	**NUMOBS**	**GPSTIME**	**OFFSET**			**Field Name**
4d 41 43 4d	02	06	0e a0 33 a0	3f b8 c0 00			Hex
ASCII Text	2	6	245380000	1.443359			Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
02	02 05	22	c1 1b 8d 09 d0 27 ee 00	7a b7 03 4b	00 97 7d 25	00 09 80 d0	Hex
2	Flags	34 (dB)	-451394.453277319670	2058814283	9927973	622800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
18	0a 05	28	c1 39 f4 6a 4c f5 33 d0	89 2b 59 77	fe 43 7e 7a	00 00 a8 f2	Hex
24	Flags	40	-1700970.30061649159	2301319543	-29131142	43250	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
07	02 05	2e	c1 33 4b c5 3d b7 31 a0	7e 59 1b 77	00 0d bf cf	00 0a 5d 53	Hex
7	Flags	46	-1264581.24107656628	2119768951	901071	679251	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
09	Aa 05	29	c1 33 ab 98 8d f9 f9 80	8c d1 3b 75	ff 64 11 ad	00 00 12 d9	Hex
9	Flags	41	-1289112.55459555984	2362522485	-10219091	4825	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
0e	02 05	25	c1 2d 7d f9 a9 25 17 a0	8b fa db bc	00 81 70 cf	00 09 de 90	Hex
14	Flag	37	-966396.83036111668	2348473276	8483032	646800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LOCKTIME**	**Field Name**
10	00 05	29	c1 37 75 8e e2 62 4e 40	84 a3 7a fc	ff 41 d6 cc	00 00 74 4f	Hex
16	Flag	38	-1537422.88431252539	2225306364	-12462388		Interpretation
CKSUM							**Field Name**
38							Hex
00111000							Interpretation

3.3.2.3.1.2 Interpretation of MACM Data Field Values.

3.3.2.3.1.2.1 Header Fields

a. <u>MACM</u>

This is the synchronization word ("sync_word"), which identifies the start of a MACM message in the midst of a stream that includes both MACM messages and other information. All data fields in the MACM message are found by counting forward from the location (offset) of the sync_word.

b. <u>NUMOBS</u>

This is a single byte whose (hexadecimal) numeric value is the number of satellite vehicles that are being tracked by the receiver, and whose data are being reported in the body of this message. Example: a value of "0a" indicates that 10 satellites are being reported.

c. <u>GPSTIME</u>

This is the GPS time of validity (called the epoch) of this particular MACM message. The times are reported in ms. A GPSTIME value of 245380000 is an actual GPS time of 245,380.000 seconds of the GPS week (Tuesday, 20 hours, 19 minutes, 40 seconds). Note: This differs from Greenwich Mean Time by the current number of leap seconds.

Times of validity for MACM records are required to be aligned with GPS time to within 2 ms and accurate to within 100 μs of true GPS time. For example, for a MACM reporting rate of 10 messages per second, one message should be valid at 245,380.000 ± 0.002 GPS seconds. The next at 245,380.100 ± 0.002, then 245,380.200 ± 0.002, etc.

When the receiver first powered up and does not know GPS time, the value of GPSTIME shall be the time in ms since power was applied.

d. <u>OFFSET</u>

This is the (residual) GPS receiver clock offset. Part of the tracking process for GPS receivers is to align the receiver clock with the true GPS time, as broadcast by the individual satellites. The clock offset is the residual error in this alignment, after the best fit has been calculated.

3.3.2.3.1.2.2 Satellite Vehicle Observation Fields

There is one observation record for each satellite being reported.

a. PRN

This is the pseudorandom noise (PRN) identification number of the satellite.
Note: Each GPS satellite has three identification numbers, a Launch Order number, a satellite vehicle number (SVN), and a PRN number. The Launch Order number is the order of satellites as they were launched. The SVN number is a serial number of the GPS satellite, assigned as it is manufactured. A typical Launch Order number is "BIIA-16", which is Block IIA satellite and was the sixteenth Block II satellite to be launched. The SVN number of BIIA-16 is 32.
As each satellite is activated, it is assigned a PRN number ranging from 1 to 32. The PRN number is actually a key number that permits the GPS receiver to demodulate the encoded GPS signal from that particular satellite. Satellite BIIA-16 is currently (April, 2000) assigned PRN number 1.

b. CONDITION

These two bytes are reserved for the sensor manufacturer to place track condition flags, warning flags, etc. The CONDITION field shall include a flag that is set if the number reported for PHASE is not valid. The CONDITION field shall also contain a flag that is set TRUE (for one message duration) when the PSRANGE field value is updated, and is FALSE otherwise.

c. CN0

The CN0 is the signal-to-noise ratio of the satellite observation in dB-Hz. The least significant bit is one dB-Hz.

d. PHASE

This is the output of the phase cycle counter. The output is in whole numbers and fractions of a carrier cycle. Each L1 carrier cycle is approximately 19.0 cm. in length, and so each change in the PHASE value of ± 1.0 represents a change in range between the satellite and the receiver of + or - 19 cm. The PHASE counter in MACM messages decrements as the range decreases and increments as the range increases.

Carrier tracking receivers report the results of carrier tracking on each satellite. If satellites and earth locations were stationary, a receiver with an oscillator tuned to exactly the GPS transmission frequency (1575.42 MHz exactly for L1, for example) could compare its phase to the broadcast satellite carrier phase and the difference would be a steady voltage. Satellites are moving; however, and the range between them and the receiver varies. As the range closes, for instance, the total number of carrier wavelengths between the satellite and receiver decreases. The receiver's difference detector shall see this difference, outputting a complete sine-wave cycle for each whole-cycle decrease in range. Carrier tracking receivers contain counters that count these difference cycles.

Phase counters both count whole numbers of cycles, and measure fractions of a cycle, in their output data. The MACM format uses a double precision floating point number for the phase number, which has approximately the number of significant figures shown in the interpretation sections of Tables V and VI. However, fractions of a phase less than 0.001 cycles are probably not significant data. The counters may start at an arbitrary initial count when the satellite is first put under track. The data that is important is the change in cycle counts from epoch to epoch.

e. PSRNGE

This is the measured (with corrections) pseudorange from the satellite to the sensor, in seconds. The measurement is scaled by a multiplication factor of 3.0×10^{10}. To convert pseudorange to meters:

$$\text{Pseudorange} = (\text{speed of light}) \times (\text{RANGE} / 3.0 \times 10^{10})$$
$$= [0.999308193 \times 10^{-2}] \times (\text{RANGE}).$$

The World Geodetic System 1984 official speed of light is 2.99792458×10^{8} m/second.

The pseudorange value must be updated at the MACM rate. The update time of validity shall be synchronized to GPS time, to within the same accuracy as the time of validity of the overall MACM message.

For MACM messages where the pseudorange is not updated, the value of the last updated pseudorange can be repeated or set to zero. (Note that the CONDITION field shall contain a flag that is TRUE at the message where pseudorange is valid, and is FALSE for messages where the pseudorange is not updated.)

f. RATE

This is the measured rate of change of the cycle counter (PHASE), in units of 10^{-4} cycles per second. To convert to cycles per second, multiply the reported number by 0.0001. There is (or should be) a close correlation between the RATE and the total increment/ decrement in the PHASE number from epoch to epoch. The sign convention for the MACM message is that RATE is positive for increasing range and PHASE count.

NOTE: This sign convention is the opposite of the actual Doppler shift of the GPS carrier. It is also the opposite to the Doppler definition of the Rinex 2 file convention.

g. LOCKTIME

This is a time counter that is incremented at 500 counts per second rate for as long as an individual satellite is maintained in continuous carrier track. The counter shall reset if carrier track is interrupted. If the lock time counter has been reset, the PHASE counter may have missed some changes in cycles, while the track was broken. (This phenomenon is called "cycle slips".)

h. CKSUM

The checksum is a method of detecting errors in the message file. The checksum shall be computed by the bit by bit exclusive ORing of all data bytes in the block of data defined in the table, and is appended to the end of the message. As an example:

Byte 1	1001	0110
Byte 2	1000	0101
Byte 3	1100	0001
Checksum	1101	0010

3.3.2.3.2 Missile Application Time Message (MATM)).
The MATM message contains the three external event time markers. The sequence of the MATM and MACM messages shall depend on the time of the external event marker input. This is covered in the GSU Specification.

3.3.2.3.2.1 Structure
MATM [4] **T1** [4] **T2** [4] **T3** [4] **CKSUM** [1]: [17 bytes total]

3.3.2.3.2.2 Data Field Definitions

MATM	Four-byte sync word. [The ASCII characters("MATM")]
T1	Four byte time stamp for input #1, μs of the hour, units of 1/10 μs.
T2	Four byte time stamp for input #2, μs of the hour, units of 1/10 μs.
T3	Four byte time stamp for input #3, μs of the hour, units of 1/10 μs.
CKSUM	One byte checksum of: T1, T2, T3.

3.3.2.3.3 Position, Velocity, Time Message Format (PVTM)
The PVTM shall contain latitude, longitude, altitude, velocity east, velocity north, velocity up, and GPS time (ms) of the week. Table VIII shows the PVTM format and number of words required.

TABLE VIII. PVTM Format

Name	Number of Bytes	Data Type	Definition
PVTM	4	Character	PVTM
Time, Millisecond of the Week	4	Unsigned Integer	Universal Time Corrected (ms)
Latitude	4	Signed Integer	+/- 90 degrees
Longitude	4	Signed Integer	+/- 180 degrees
Altitude	4	Signed Integer	+/- Feet Corrected for Mean Sea Level
East Velocity	2	Signed Integer	+/- 65,535 feet/second
North Velocity	2	Signed Integer	+/- 65,535 feet/second
Up Velocity	2	Signed Integer	+/- 65,535 feet/second
CKSUM	1	Integer	Checksum includes all bytes through the end of message except PVTM and CKSUM.

3.3.2.4 TUMS Type II GSU structure
The TUMS Type II GSU message structure shall contain a vendor specified GSU message within the overall TUMS statement. The maximum length of the vendor GSU message per epoch is 950 bytes.

3.3.2.5 IMU Data structure

The overall IMU data structure is shown in Table IX.

3.3.2.5.1 Timing and sampling relationships

The basic timing is generated by the GSU EPS. The period (duration) of the EPS is defined as 1 epoch. One GSU message is output to the formatter every epoch. The GSU cyclic timing as it affects the TUMS message is covered in the JTU specification. During the GSU epoch period all six IMU analog sensors are simultaneously sampled at the IMU rate. The IMU sampling rate is also generated by the GSU and is synchronized to the leading edge of the GSU pulse. The IMU sampling rate is a fixed integer value several magnitudes higher than the GSU rate to allow for the IMU sampling and data processing during a single GSU epoch pulse. The details of the timing relationships are covered in the GSU specifications. The IMU data structure will vary only with the number (N_G) of samples of processed and accumulated data per GSU epoch as discussed in this paragraph.

Table IX. IMU Message Structure

	Header (3)	**Counter** (2)							$T=t_0 + n^* T_I$ ($n=0$ to N_G)
	∑ΔVx(3)	∑ΔVy(3)	∑ΔVz(3)	∑Q0(3)	∑Qx(3)	∑Qy(3)	∑Qz(3)		$T=t_0$
	∑ΔVx(3)	∑ΔVy(3)	∑ΔVz(3)	∑Q0(3)	∑Qx(3)	∑Qy(3)	∑Qz(3)		$T= t_0 + 1^*T_I$
∑	∑ΔVx(3)	∑ΔVy(3)	∑ΔVz(3)	∑Q0(3)	∑Qx(3)	∑Qy(3)	∑Qz(3)		$T= t_0 + 2^*T_I$
	∑ΔVx(3)	∑ΔVy(3)	∑ΔVz(3)	∑Q0(3)	∑Qx(3)	∑Qy(3)	∑Qz(3)		$T= t_0 + 3^*T_I$
				.					.
				.					.
	∑ΔVx(3)	∑ΔVy(3)	∑ΔVz(3)	∑Q0(3)	∑Qx(3)	∑Qy(3)	∑Qz(3)		$T= t_0+ N_G^*T_I$
	Check Sum(1)								

Key: T = Accumulation time stamp
t_0 = Epoch begin time
T_I = Integration period (secs) ($N_I^*T_R$)
N_G = Number of accumulation samples for each epoch period
(x) = (bytes)

3.3.2.5.2 Header

The Header shall contain the ASCII characters "IMU”

3.3.2.5.3 Counter

This shall be a two-byte word consisting of the total number of bytes contained in the IMU message starting with and including the counter and ending with the last accumulation block.

3.3.2.5.4 Accumulated data structure

3.3.2.5.4.1 Accumulated Delta Velocities

The acceleration data in the x, y and z directions is sampled at the IMU sample rate. Each sample is then processed into integrated delta velocities in each axis, converted into engineering units of 0.1mm/sec and summed to the previous accumulated delta velocity to produce the new accumulated delta velocity for each direction ($\sum\Delta Vx$, $\sum\Delta Vy$, $\sum\Delta Vz$). The output for each direction is a 3-byte integer number.

3.3.2.5.4.2 Accumulated Quaternion values

The angular rate data for each axis is sampled at the IMU sample rate. Each sample is then integrated and calibration corrections applied. The three sets of data are then processed through an attitude reference quaternion that produces a quaternion scalar (Q0) and three vector components (Qx,Qy,Qz). Each quaternion result is then multiplied by 2^{23} to provide an integer value with the proper resolution. Each of these four sets of processed data is added to the previous accumulated quaternion values to produce four new accumulated values ($\sum Q0$, $\sum Qx$, $\sum Qy$, $\sum Qz$). The output is a 3-byte unitless integer for each data sample.

3.3.2.5.5 Checksum

This is a one-byte checksum of the starting at the first bit after the IMU header. The checksum shall be calculated using XOR.

3.3.2.6 Packet Data Field Checksum

The last parameter of the Packet Data Field is a one-byte checksum starting at the first bit after the packet header. The checksum shall be calculated using XOR.

3.4 TUMS Message Nomenclature

The TUMS format will vary depending on the GSU, sample rates, etc. but will be fixed for a given set of hardware. The JTU will contain a unit nomenclature alphanumeric series on the unit ID label that shall identify the structure of the TUMS message and thereby define the configuration of the particular unit. This nomenclature shall be composed as follows:
TUMS Type – GSU Rate – IMU Rate – Integration Factor (N)

For example, a TUMS packet that uses a MACM GSU message at a rate of 10 Hz, has an IMU measurement rate of 1000 Hz and a factor of 5 for the IMU integration, the nomenclature would be: “I-10-1000-5”
This nomenclature will be input to the JDP “Personality Module” which will allow the JDP to properly process the TUMS message.

4.0 Verification

4.1 Verification of TUMS Data

TUMS Data Protocol requirements shall be in accordance with the applicable JAMI GPS system specification

5.0 Packaging

N/A

6.0 Notes

This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Intended use

The JAMI TUMS is the basic message format for the telemetry transmission of the GPS and inertial data from the air vehicle to the JAMI Ground Processor Unit. This digital format will be the JAMI system intercommunications standard.

6.2 Acquisition Requirements

Verification of TUMS Data Protocol requirements shall be in accordance with the applicable JAMI GPS system specifications.

6.3 Coordination with other documentation.

Specific requirements of this specification have been coordinated with Raytheon, Inc. drawing 7030036, Interface Control Document for the Advanced Medium Range Air to Air Missile.

6.4 Abbreviations and acronyms

BIT	Built in test
CKSUM	Check sum
cm	Centimeters
dB	Decibels
DC	Direct Current
deg	Degrees
EPS	Epoch pulse strobe
GHz	GigaHertz
GPS	Global positioning system
GSU	GPS sensor unit
Hz	Hertz (indicates samples per second, i.e., data rate)
ID	Identification
IMU	Inertial measurement unit
IRIG	International range instrumentation group
JAMI	Joint Advanced Missile Instrumentation
JDP	JAMI data processor
JTU	JAMI TSPI unit

JTUDFB	JTU data formatter board
KHz	Kilohertz
LSB	Least significant bit
m	Milli (unit prefix), Meters
ma	Milliampere
MACM	Missile Application Condensed Measurements
MATM	Missile Application Time Message
MHz	Mega Hertz
MSB	Most significant bit
mm	Millimeter
ms	Millisecond
NAWC	Naval Air Weapons Center
ns	Nano seconds
Period (sec)	Inverse of samples per second (1/Hz)
PVTM	Position, Velocity, Time Message
Sec, sec	Seconds
TM	Telemetry
TSPI	Time-Space-Position Information
TUMS	TSPI Unit Message Structure
μs	Microseconds